

## UNITED STATES PATENT OFFICE

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## TURBINE BLADING

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My invention relates to reaction turbines, more particularly to those having elastic fluid supplied thereto at relatively high pressure and having a relatively small ratio of inlet pressure to back pressure, otherwise stated, a low pressure or expansion ratio; and it has for an object to improve the efficiency of such turbines by suitable choice of the blade gauging.

A more particular object of the invention is to improve the efficiency of reaction turbines designed for nearly constant stage velocity ratio, and having a small expansion ratio, with steam supplied thereto at high absolute initial pressure. The principal effect of the invention is, therefore, to improve the performance of high-pressure units of multi-cylinder turbines and of topping turbines, where such machines are used for driving alternators, this use requiring constant speed to give a predetermined frequency and, largely on that account, permitting the designer to approach optimum stage velocity ratios independent of large changes in load. While a turbine driving an alternator may be regarded as a constant speed machine, the invention is not necessarily limited to one of this constant speed type for the reason that it may be applied to other high-pressure units, such as those of multi-cylinder marine turbines, where the steam is so admitted to the high-pressure unit that the ratio of blade speed to steam speed, that is, the velocity ratio, is maintained substantially constant.

In many cases a reaction stage is the most efficient type and is to be preferred, where the volumetric flows lead to favorable aspect ratios,  $h/l$ . The present invention is of particular interest in connection with turbines of large rating, designed for constant stage velocity ratio, relatively small pressure or expansion ratio, for example, high-pressure units of compound arrangements and topping turbines where emphasis is placed on the rated load performance, that is, is on base load performance.

To develop a desired power ( $kw$ ) a certain flow is needed, and, with preassigned fluid conditions at the inlet and the outlet, certain areas are required in the various stages. Passage area is largely fixed by blade height,  $h$ , and gauging,  $o/s$ , where  $o$  is the opening between adjacent blades and  $s$  is the pitch. With turbines of the foregoing type, dense motive fluid is employed with the result that the loading for each blade may be relatively high; and, on this account, the blade section measured by the chord dimension,  $l$ , must be sufficiently large to provide adequate

strength. For blade heights contemplated, the upper limit of aspect ratios,  $h/l$ , will be of the order of 3 or, perhaps, 4. The range of aspect ratios is relatively very much smaller for a turbine of the low expansion ratio type than for one of the condensing type. Representative ranges of expansion ratios might be, for example, ten (10) in a turbine with an inlet pressure of 1000 lbs./sq. in. and a back pressure of 100 lbs./sq. in., and one thousand (1000) in a turbine with an inlet pressure of 500 lbs./sq. in. and a back pressure of 0.5 lb./sq. in. Heretofore, it has been common practice to maintain a constant gauging, for example, 30%, and to calculate the blade heights or aspect ratios to give the needed flow area. I find that, for the required flow area ratios,  $h/l \times o/s$ , (expressed dimensionlessly to conveniently restrict experiments and facilitate presentation of results) optimum stage efficiencies occur at various gaugings, and, if both the gauging and the blade height are varied, advantageous combinations may be chosen. Also, I find that, as the flow area ratio,  $h/l \times o/s$ , diminishes, the rate of change of efficiency with gauging, for favorable velocity ratios, increases.

Accordingly, a further object of the invention is to provide a reaction turbine of the favorable velocity ratio and low expansion ratio type, wherein the gauging is smaller at the high-pressure end than at the low-pressure end thereof.

A further object of the invention is to provide a reaction turbine of the type described, wherein, because the rate of change of efficiency with gauging increases rapidly with decreasing flow area ratios,  $h/l \times o/s$ , the gauging is selected to attain optimum stage efficiency or nearly so. Conversely, as the necessary flow area ratio increases, the rate of change of efficiency with gauging decreases until values of the parameter  $h/l \times o/s$  are reached where very little change in efficiency occurs with change in gauging so that, therebeyond to larger flow area ratios, the matter of a preferential gauging may be disregarded, and within wide limits, gauging may be arbitrarily selected so as to give the required flow area ratio together with the aspect ratio.

These and other objects are effected by the invention as will be apparent from the following description and claims taken in connection with the accompanying drawing, forming a part of this application, in which:

Fig. 1 is a detail sectional view of a low expansion ratio turbine employing the new arrangement of blading;